Consiglio Nazionale delle Ricerche
Istituto di Elettronica e di Ingegneria dell'Informazione e delle Telecomunicazioni

Thesis proposal on
Development of Processor- and Hardware-In-the-Loop Simulators for Assessing Unmanned Aerial Vehicle Performance in Pesticide Spraying Operations on Vineyards

The adoption of Unmanned Aerial Vehicles (UAVs) in agricultural scenarios can aspire to become a reality if the validation of their effectiveness is sustained by the contemporary and shared improvement of all those technological gaps identified by current research projects. In particular, a crucial point is still missing: the interconnection among the distribution systems/implements and the guidance, navigation and control (GNC) capabilities provided to the drones. For what concern crop protection, an innovative approach should provide equal relevance to both the distribution efficiency and the effectiveness of the GNC scheme by optimizing the spraying spread to ensure effective pesticide release with low-risk for human health and the environment, and reducing the amount of pesticide with respect to the design of the optimal path-to-follow and the robust control of the vehicle, the latter to face both modeling uncertainty and external environmental disturbances and to avoid collisions.

Fig. 1 - UAV operating in a vineyard.

Fig. 2 – Pixhawk 4 autopilot.

This thesis is aimed to the development of a reliable and flexible simulation environment to reproduce the flight dynamics of a multirotor UAV in scenarios where UAVs may represent a favorable alternative to conventional machines, i.e. vineyard on sloped areas (see Fig. 1), while integrating the Pixhawk 4 microcontroller (see Fig. 2) in the loop. The Pixhawk 4 microcontroller comes pre-installed with the latest PX4 firmware and allows to implement more complex algorithms and models on the autopilot. This would represent the second step for the on-board flight software validation via Processor-In-the-Loop (PIL) testing campaigns, i.e. executing the guidance, navigation and control (GNC) algorithm for real-time execution on the dedicated microcontroller while the modeling environment is running on a separated host platform. In particular, the PIL multi-rate simulator will retrace the architecture of the SIL simulator and it shall include proper communication interfaces with the aircraft modeling environment developed in MATLAB/Simulink.

The candidate will develop the PIL simulator and related library, retracing the architecture of the related SIL simulator and providing appropriate communication interface among the host platform and the development board, i.e. the Pixhawk 4 autopilot. The candidate will also provide a proper software suite for (real-time or post-processing) visualization of the UAV flight path within a virtual environment. Furthermore, the candidate has to set the PIL simulator to ease the next phase of the flight software validation, i.e. Hardware-In-the-Loop validation. In this last validation phase, the Pixhawk will host the entire flight software that will be run on-board the autopilot, without any support provided by external host platforms.

Bibliography:

- Mammarella M., Ristorto G., Capello E., Bloise N., Guglieri G., Dabbene F. "*Waypoint Tracking via Tube-based Robust Model Predictive Control for Crop Monitoring with Fixed-Wing UAVs*", In: 2019 IEEE International Workshop on Metrology for Agriculture and Forestry (MetroAgriFor). IEEE, 2019, p. 19-24.
- Mammarella M., Capello E., Dabbene F., Guglieri G., "*Sample-Based SMPC for Tracking Control of Fixed-Wing UAV*", In: IEEE control systems letters, IEEE, 2018, vol. 2 (4), p. 611-616.
- Additional material will be provided to complete the background.

Skills:

- Excellent knowledge of computer science and programming
- Excellent knowledge of system modeling
- Excellent skills on model-based software design
- Basics of automatic control
- Excellent coding skills in MATLAB/Simulink
- Excellent coding skill in C/C++
- Basic knowledge of ROS

Keywords: Precision farming, Unmanned Aerial Vehicle, Optimal Predictive Control, Processor-In-the-Loop validation, Hardware-In-the-Loop validation.

Starting Date: March 2020.

Advisors and Stage: The thesis will be carried out under the supervision of the staff of the System and Modeling Control Group at the Institute of Electronics, Computer and Telecommunication Engineering of National Research Council of Italy (IEIIT-CNR). Possible collaborations with Prof. Paolo Gay research group of the Dipartimento di Scienze Agrarie, Forestali e Alimentari (DISAFA) of the Università degli Studi di Torino (www.disafa.unito.it) and with Prof. Giorgio Guglieri research group of the Dipartimento di Ingegneria Meccanica ed Aerospaziale (DIMEAS) of Politecnico di Torino (www.dimeas.polito.it).

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If interested, please send your CV with a complete lists of exams and votes.